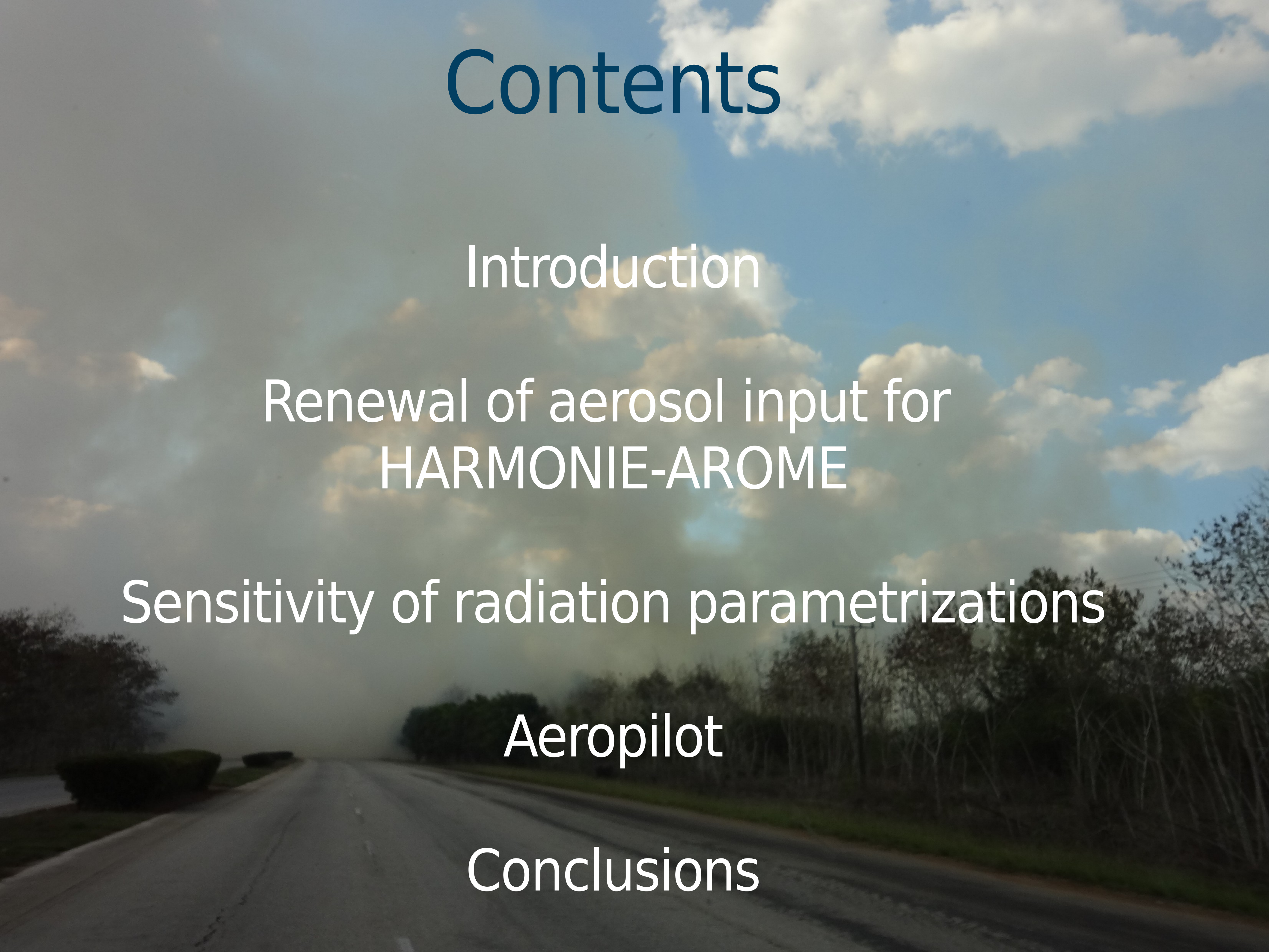
About aerosol strategies and tactics

Laura Rontu FMI
Emily Gleeson Daniel Martin Velle Toll Kristian Pagh Nielsen
MetEireann AEMET U.Tartu DMI
Serguei Ivanov Ashour Sassi OSENU

1 April 2020
Joint 30th ALADIN Workshop & HIRLAM All Staff Meeting
Videoconference based on Ljubljana, Slovenia / Toulose, France



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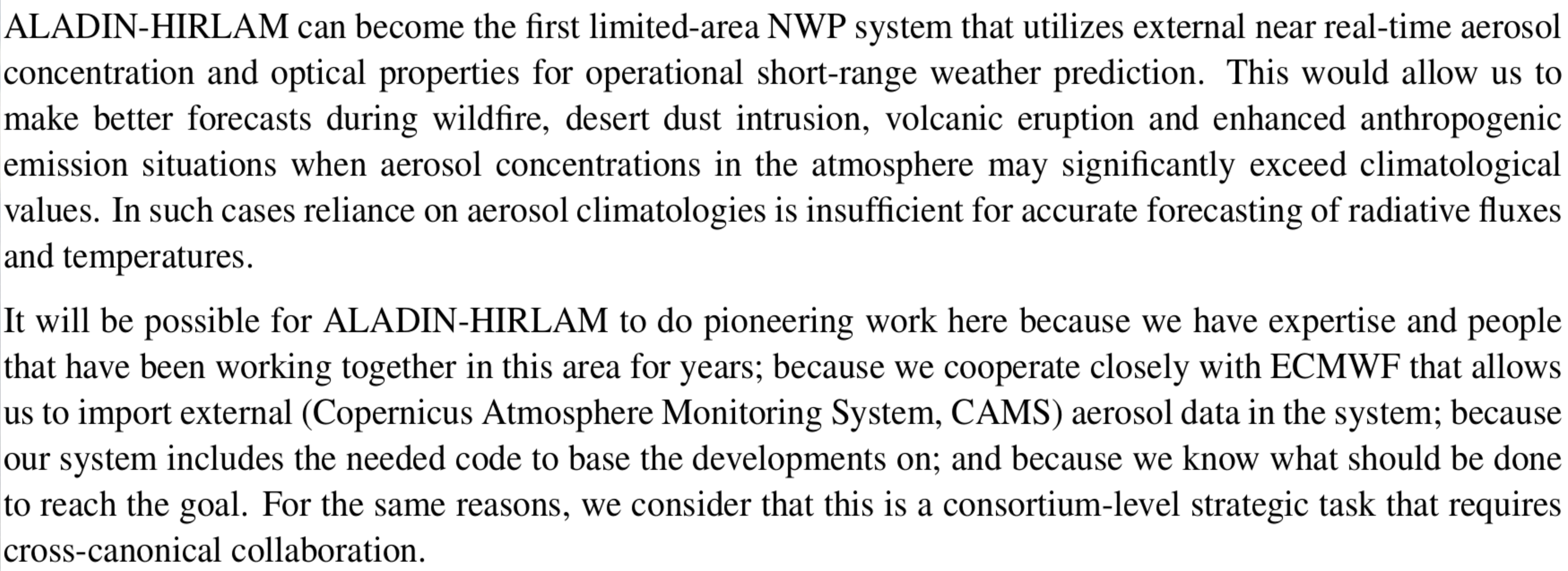
Suggested for the strategy discussions:

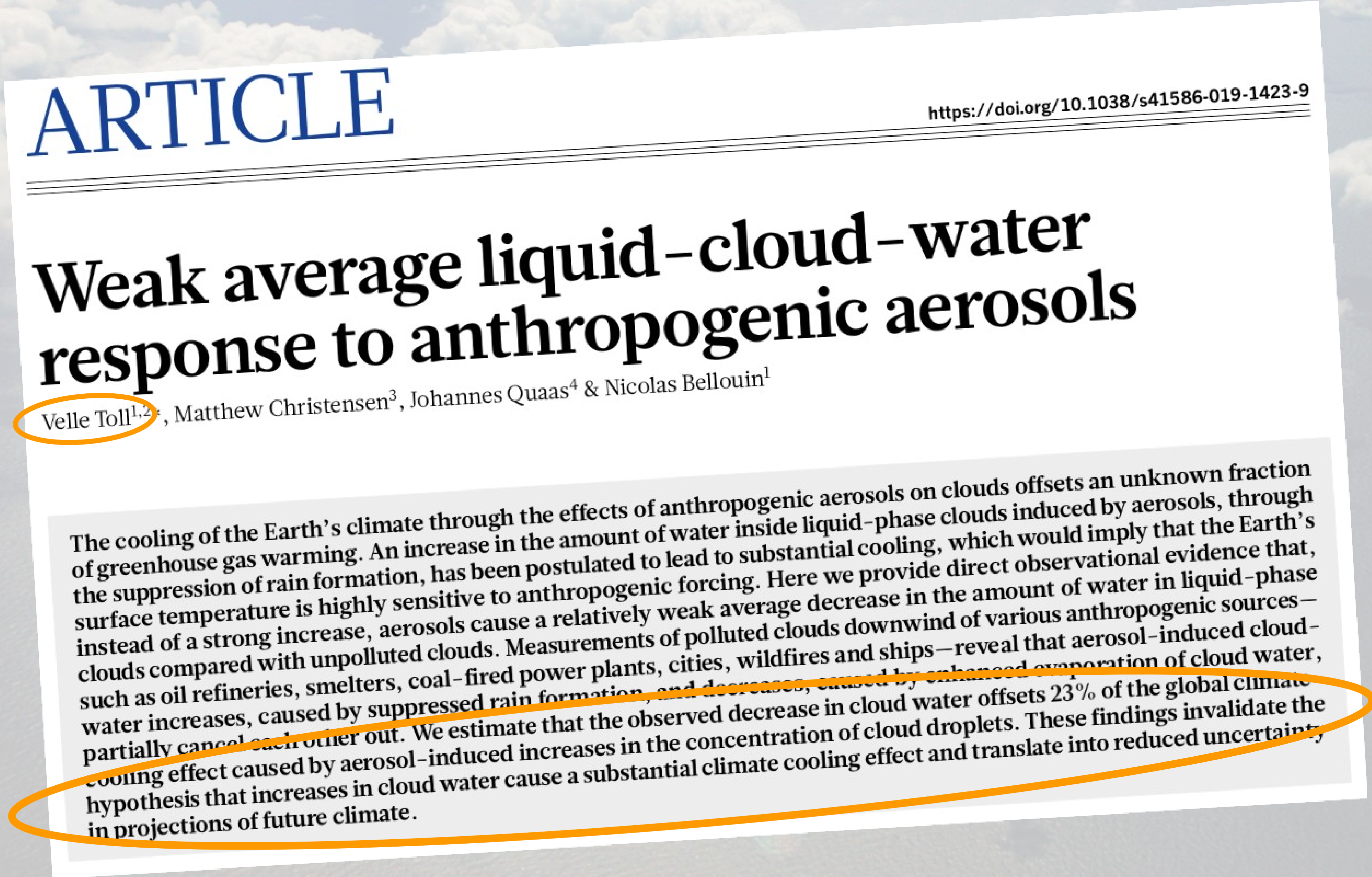


ALADIN-HIRLAM can become the first limited-area NWP system that utilizes external near real-time aerosol concentration and optical properties for operational short-range weather prediction. This would allow us to make better forecasts during wildfire, desert dust intrusion, volcanic eruption and enhanced anthropogenic emission situations when aerosol concentrations in the atmosphere may significantly exceed climatological values. In such cases reliance on aerosol climatologies is insufficient for accurate forecasting of radiative fluxes and temperatures.

It will be possible for ALADIN-HIRLAM to do pioneering work here because we have expertise and people that have been working together in this area for years; because we cooperate closely with ECMWF that allows us to import external (Copernicus Atmosphere Monitoring System, CAMS) aerosol data in the system; because our system includes the needed code to base the developments on; and because we know what should be done to reach the goal. For the same reasons, we consider that this is a consortium-level strategic task that requires cross-canonical collaboration.

Cross-canonical collaboration needed!

Recently, several important articles published about aerosol impacts, properties, data available



ARTICLE

https://doi.org/10.1038/s41586-019-1423-9

Weak average liquid-cloud-water response to anthropogenic aerosols

Velle Toll[1,2], Matthew Christensen[3], Johannes Quaas[4] & Nicolas Bellouin[1]

The cooling of the Earth's climate through the effects of anthropogenic aerosols on clouds offsets an unknown fraction of greenhouse gas warming. An increase in the amount of water inside liquid-phase clouds induced by aerosols, through the suppression of rain formation, has been postulated to lead to substantial cooling, which would imply that the Earth's surface temperature is highly sensitive to anthropogenic forcing. Here we provide direct observational evidence that, instead of a strong increase, aerosols cause a relatively weak average decrease in the amount of water in liquid-phase clouds compared with unpolluted clouds. Measurements of polluted clouds downwind of various anthropogenic sources—such as oil refineries, smelters, coal-fired power plants, cities, wildfires and ships—reveal that aerosol-induced cloud-water increases, caused by suppressed rain formation, and decreases, caused by enhanced evaporation of cloud water, partially cancel each other out. We estimate that the observed decrease in cloud water offsets 23% of the global climate cooling effect caused by aerosol-induced increases in the concentration of cloud droplets. These findings invalidate the hypothesis that increases in cloud water cause a substantial climate cooling effect and translate into reduced uncertainty in projections of future climate.

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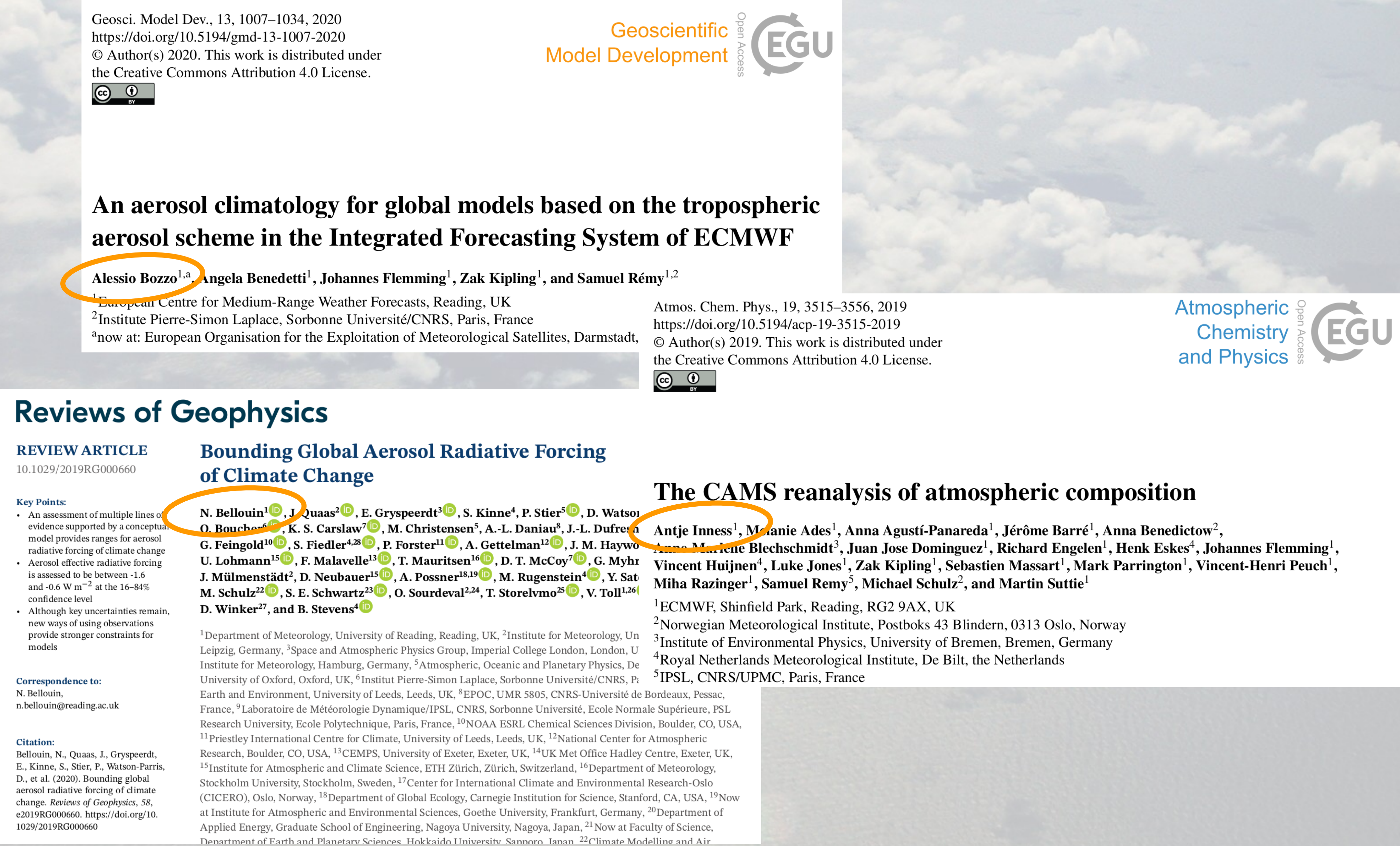

Geosci. Model Dev., 13, 1007–1034, 2020
https://doi.org/10.5194/gmd-13-1007-2020

Geoscientific
Model Development
Open Access
EGU

An aerosol climatology for global models based on the tropospheric aerosol scheme in the Integrated Forecasting System of ECMWF

Alessio Bozzo[1,a], **Angela Benedetti**[1], **Johannes Flemming**[1], **Zak Kipling**[1], **and Samuel Rémy**[1,2]
[1]European Centre for Medium-Range Weather Forecasts, Reading, UK
[2]Institute Pierre-Simon Laplace, Sorbonne Université/CNRS, Paris, France
[a]now at: European Organisation for the Exploitation of Meteorological Satellites, Darmstadt,

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Atmos. Chem. Phys., 19, 3515–3556, 2019
https://doi.org/10.5194/acp-19-3515-2019

Atmospheric
Chemistry
and Physics
Open Access
EGU

The CAMS reanalysis of atmospheric composition

Antje Inness[1], **Mélanie Ades**[1], **Anna Agustí-Panareda**[1], **Jérôme Barré**[1], **Anna Benedictow**[2], **Anne-Marlene Blechschmidt**[3], **Juan Jose Dominguez**[1], **Richard Engelen**[1], **Henk Eskes**[4], **Johannes Flemming**[1], **Vincent Huijnen**[4], **Luke Jones**[1], **Zak Kipling**[1], **Sebastien Massart**[1], **Mark Parrington**[1], **Vincent-Henri Peuch**[1], **Miha Razinger**[1], **Samuel Remy**[5], **Michael Schulz**[2], **and Martin Suttie**[1]
[1]ECMWF, Shinfield Park, Reading, RG2 9AX, UK
[2]Norwegian Meteorological Institute, Postboks 43 Blindern, 0313 Oslo, Norway
[3]Institute of Environmental Physics, University of Bremen, Bremen, Germany
[4]Royal Netherlands Meteorological Institute, De Bilt, the Netherlands
[5]IPSL, CNRS/UPMC, Paris, France

Reviews of Geophysics

REVIEW ARTICLE

10.1029/2019RG000660

Bounding Global Aerosol Radiative Forcing of Climate Change

N. Bellouin[1], **J. Quaas**[2], **E. Gryspeerdt**[3], **S. Kinne**[4], **P. Stier**[5], **D. Watso**
O. Boucher[6], **K. S. Carslaw**[7], **M. Christensen**[5], **A.-L. Daniau**[8], **J.-L. Dufres**
G. Feingold[10], **S. Fiedler**[4,28], **P. Forster**[11], **A. Gettelman**[12], **J. M. Haywo**
U. Lohmann[15], **F. Malavelle**[13], **T. Mauritsen**[16], **D. T. McCoy**[7], **G. Myhr**
J. Mülmenstädt[2], **D. Neubauer**[15], **A. Possner**[18,19], **M. Rugenstein**[4], **Y. Sat**
M. Schulz[22], **S. E. Schwartz**[23], **O. Sourdeval**[2,24], **T. Storelvmo**[25], **V. Toll**[1,26]
D. Winker[27], **and B. Stevens**[4]

[1]Department of Meteorology, University of Reading, Reading, UK, [2]Institute for Meteorology, Un
Leipzig, Germany, [3]Space and Atmospheric Physics Group, Imperial College London, London, U
Institute for Meteorology, Hamburg, Germany, [5]Atmospheric, Oceanic and Planetary Physics, De
University of Oxford, Oxford, UK, [6]Institut Pierre-Simon Laplace, Sorbonne Université/CNRS, Pa
Earth and Environment, University of Leeds, Leeds, UK, [8]EPOC, UMR 5805, CNRS-Université de Bordeaux, Pessac, France, [9]Laboratoire de Météorologie Dynamique/IPSL, CNRS, Sorbonne Université, Ecole Normale Supérieure, PSL Research University, Ecole Polytechnique, Paris, France, [10]NOAA ESRL Chemical Sciences Division, Boulder, CO, USA, [11]Priestley International Centre for Climate, University of Leeds, Leeds, UK, [12]National Center for Atmospheric Research, Boulder, CO, USA, [13]CEMPS, University of Exeter, Exeter, UK, [14]UK Met Office Hadley Centre, Exeter, UK, [15]Institute for Atmospheric and Climate Science, ETH Zürich, Zürich, Switzerland, [16]Department of Meteorology, Stockholm University, Stockholm, Sweden, [17]Center for International Climate and Environmental Research-Oslo (CICERO), Oslo, Norway, [18]Department of Global Ecology, Carnegie Institution for Science, Stanford, CA, USA, [19]Now at Institute for Atmospheric and Environmental Sciences, Goethe University, Frankfurt, Germany, [20]Department of Applied Energy, Graduate School of Engineering, Nagoya University, Nagoya, Japan, [21]Now at Faculty of Science, Department of Earth and Planetary Sciences, Hokkaido University, Sapporo, Japan, [22]Climate Modelling and Air

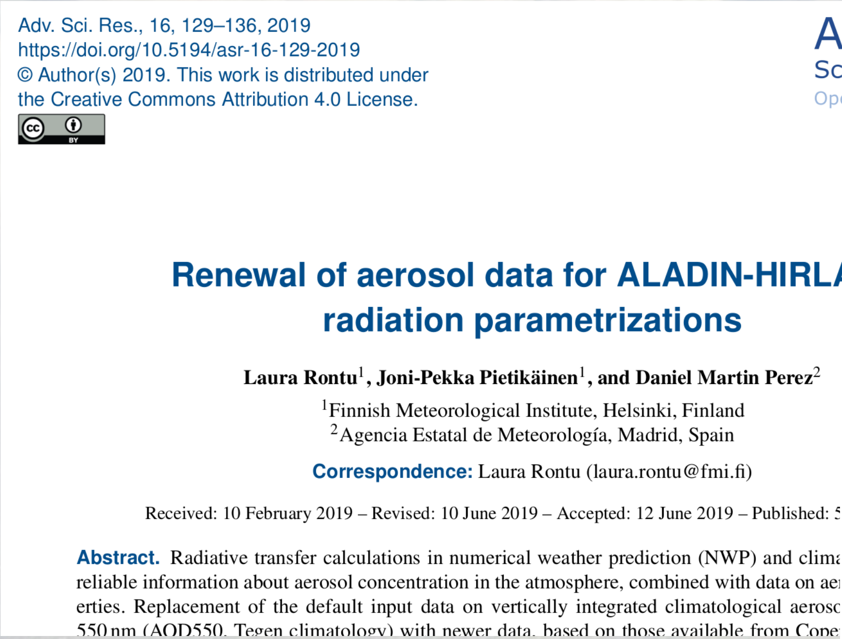
Key Points:

- An assessment of multiple lines of evidence supported by a conceptual model provides ranges for aerosol radiative forcing of climate change
- Aerosol effective radiative forcing is assessed to be between -1.6 and -0.6 W m^{-2} at the 16–84% confidence level
- Although key uncertainties remain, new ways of using observations provide stronger constraints for models

Correspondence to:
N. Bellouin,
n.bellouin@reading.ac.uk

Citation:
Bellouin, N., Quaas, J., Gryspeerdt, E., Kinne, S., Stier, P., Watson-Parris, D., et al. (2020). Bounding global aerosol radiative forcing of climate change. *Reviews of Geophysics*, *58*, e2019RG000660. https://doi.org/10.1029/2019RG000660

Studies within ALADIN-HIRLAM limited area system have been reported, focusing on the radiative impacts of aerosols and aerosol data



Adv. Sci. Res., 16, 129–136, 2019
https://doi.org/10.5194/asr-16-129-2019

Advances in
Science & Research
Open Access Proceedings

18th EMS Annual Mee

Renewal of aerosol data for ALADIN-HIRLAM radiation parametrizations

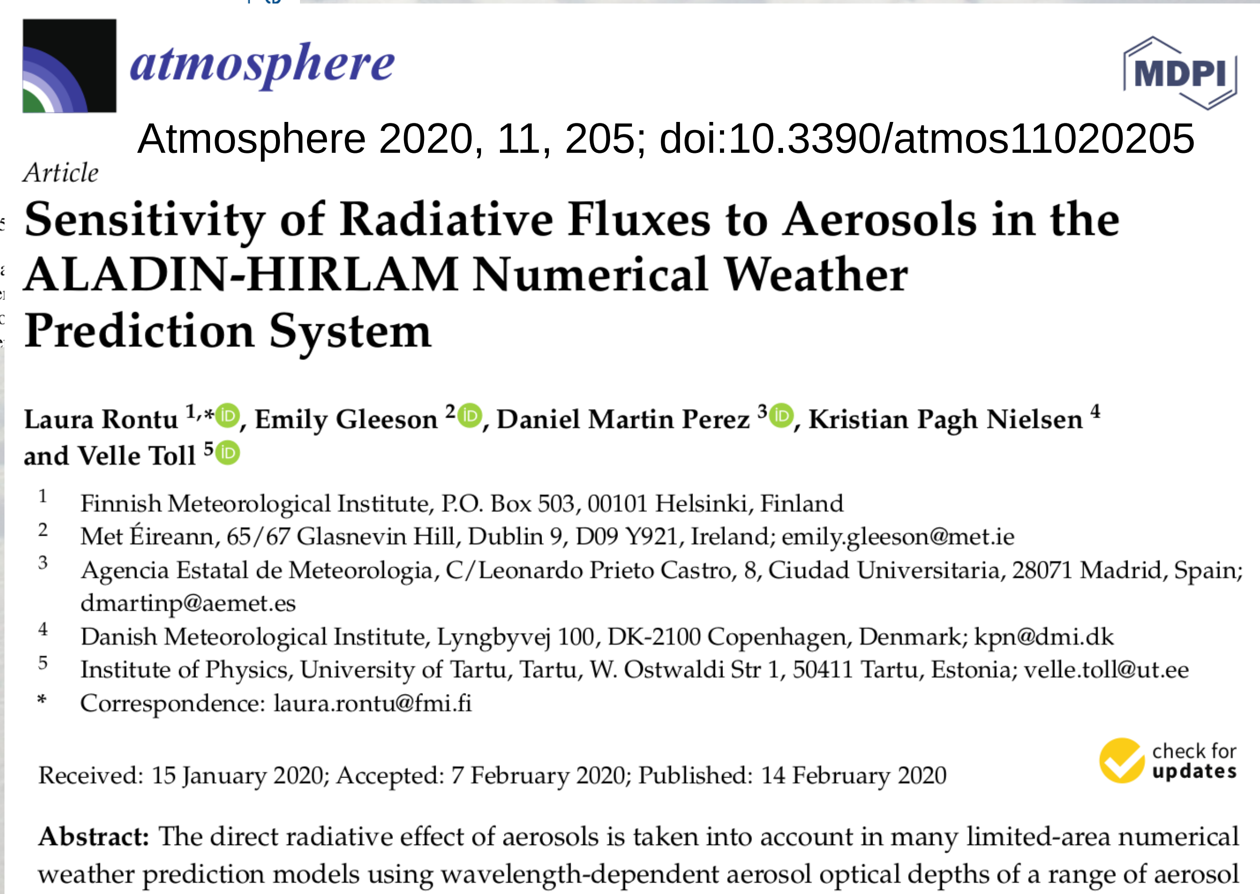
Laura Rontu[1], **Joni-Pekka Pietikäinen**[1], **and Daniel Martin Perez**[2]

[1]Finnish Meteorological Institute, Helsinki, Finland
[2]Agencia Estatal de Meteorología, Madrid, Spain

Correspondence: Laura Rontu (laura.rontu@fmi.fi)

Received: 10 February 2019 – Revised: 10 June 2019 – Accepted: 12 June 2019 – Published: 5

Abstract. Radiative transfer calculations in numerical weather prediction (NWP) and clima
reliable information about aerosol concentration in the atmosphere, combined with data on ae
erties. Replacement of the default input data on vertically integrated climatological aerosc
550 nm (AOD550, Tegen climatology) with newer data, based on those available from Cope



atmosphere

MDPI

Atmosphere 2020, 11, 205; doi:10.3390/atmos11020205

Article

Sensitivity of Radiative Fluxes to Aerosols in the ALADIN-HIRLAM Numerical Weather Prediction System

Laura Rontu [1,*], Emily Gleeson [2], Daniel Martin Perez [3], Kristian Pagh Nielsen [4] and Velle Toll [5]

1 Finnish Meteorological Institute, P.O. Box 503, 00101 Helsinki, Finland
2 Met Éireann, 65/67 Glasnevin Hill, Dublin 9, D09 Y921, Ireland; emily.gleeson@met.ie
3 Agencia Estatal de Meteorologia, C/Leonardo Prieto Castro, 8, Ciudad Universitaria, 28071 Madrid, Spain; dmartinp@aemet.es
4 Danish Meteorological Institute, Lyngbyvej 100, DK-2100 Copenhagen, Denmark; kpn@dmi.dk
5 Institute of Physics, University of Tartu, Tartu, W. Ostwaldi Str 1, 50411 Tartu, Estonia; velle.toll@ut.ee
* Correspondence: laura.rontu@fmi.fi

Received: 15 January 2020; Accepted: 7 February 2020; Published: 14 February 2020

check for updates

Abstract: The direct radiative effect of aerosols is taken into account in many limited-area numerical weather prediction models using wavelength-dependent aerosol optical depths of a range of aerosol

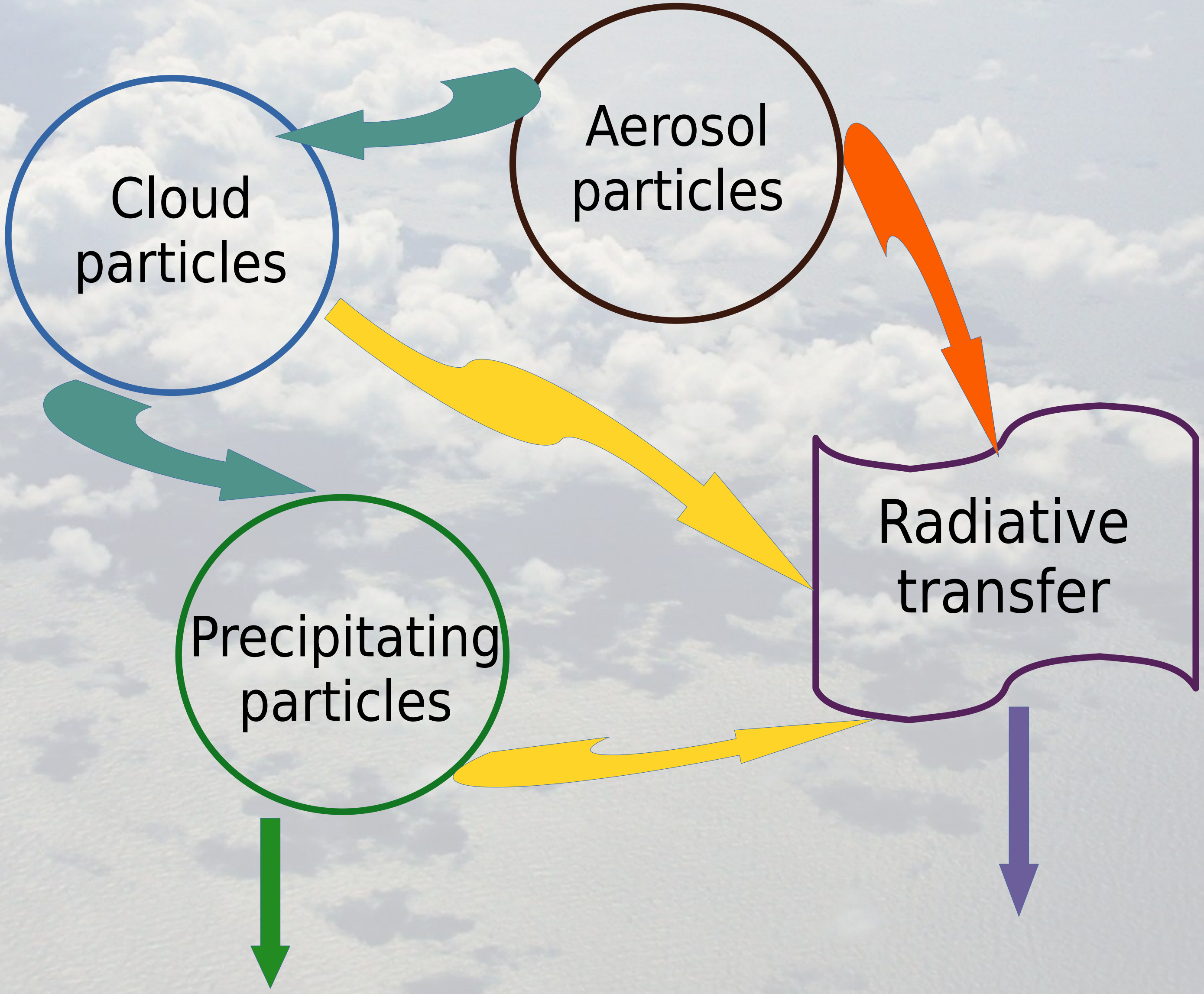
http://www.umr-cnrm.fr/aladin/IMG/pdf/martin-perez_asm2018_toulouse.pdf

http://www.umr-cnrm.fr/aladin/IMG/pdf/martin_daniel_aemet_asm2019_madrid_3.pdf

Daniel Martin: Update of the Use of CAMS aerosols in HARMONIE-AROME, asm2020

Parametrization of microphysics and optical properties

Shown in ASW19:



Cloud particles

Aerosol particles

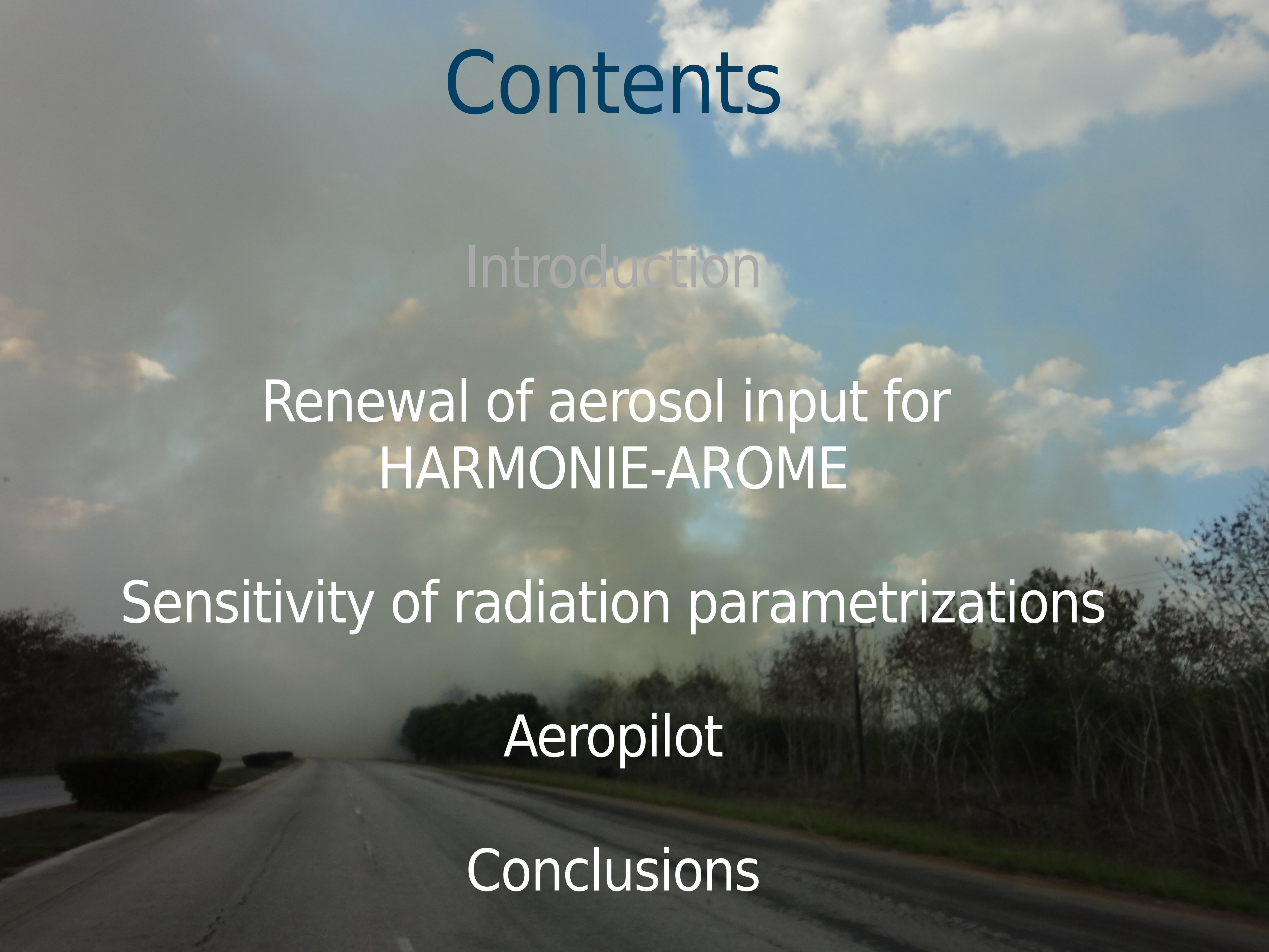
Precipitating particles

Radiative transfer

optical and
microphysical
properties
radiation
precipitation

Solid, liquid precipitation

Solar, terrestrial radiation



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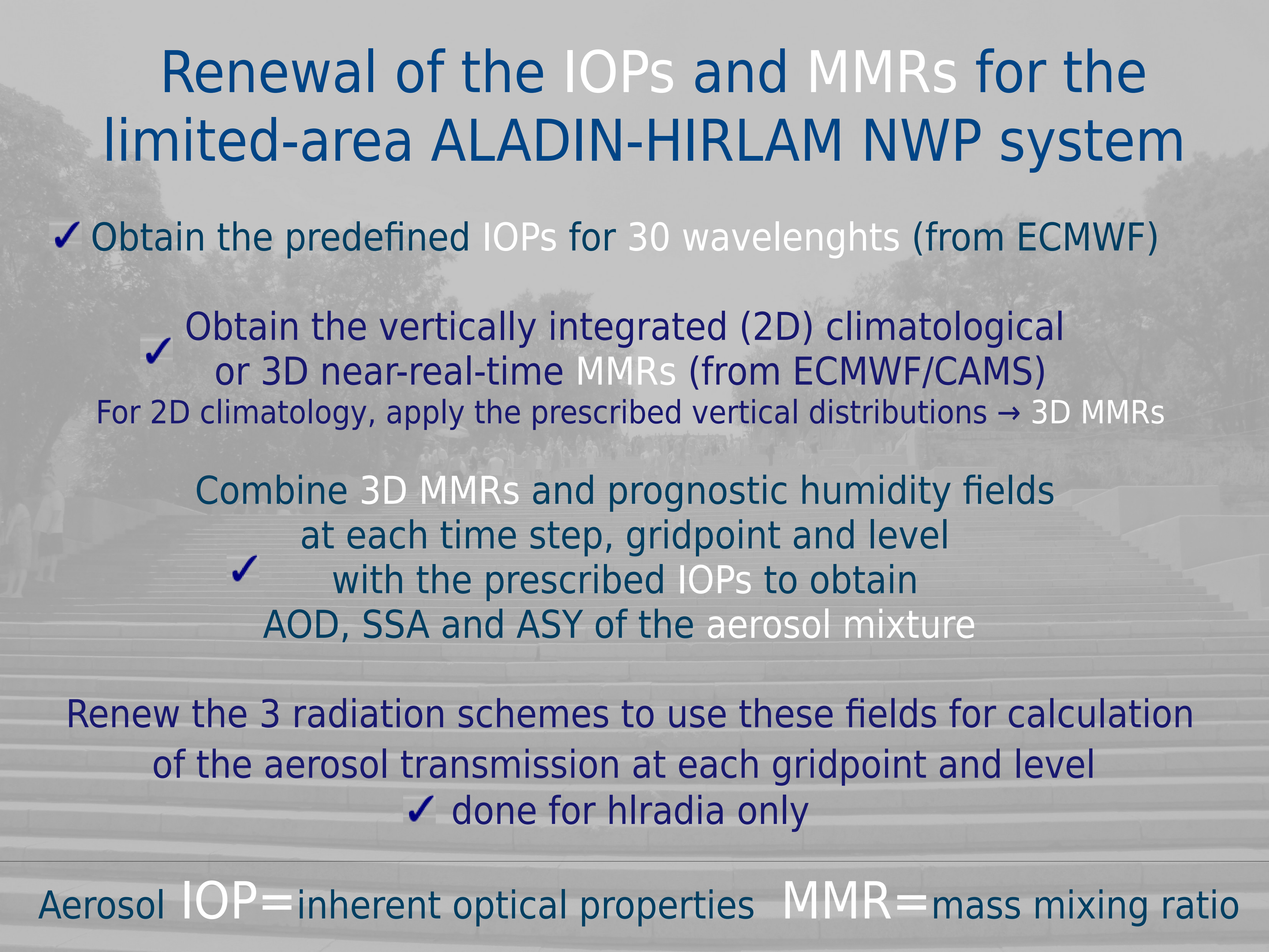


Renewal of the IOPs and MMRs for the limited-area ALADIN-HIRLAM NWP system

✓ Obtain the predefined IOPs for 30 wavelenghts (from ECMWF)

✓ Obtain the vertically integrated (2D) climatological or 3D near-real-time MMRs (from ECMWF/CAMS)

For 2D climatology, apply the prescribed vertical distributions → 3D MMRs

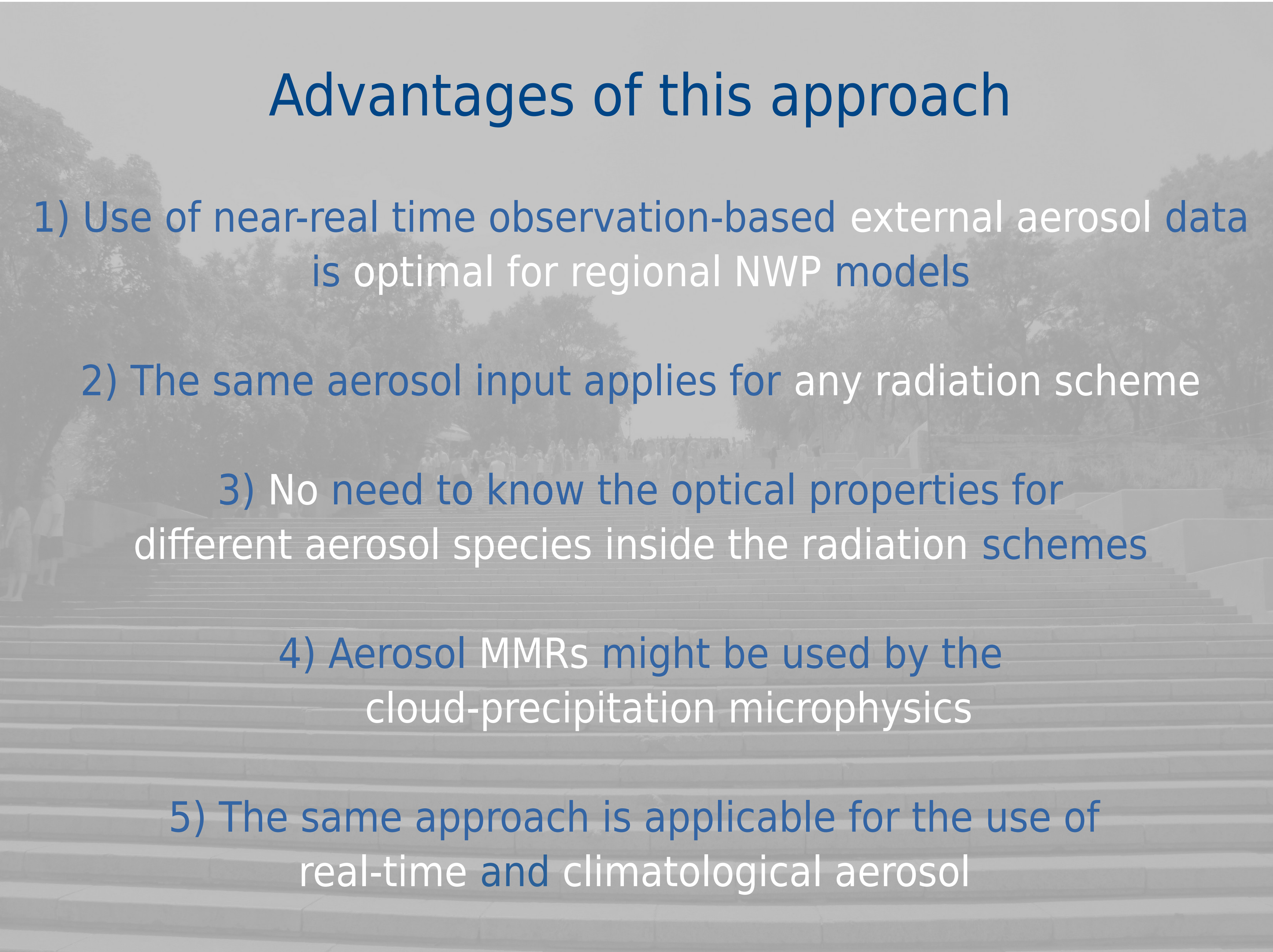
✓ Combine 3D MMRs and prognostic humidity fields
at each time step, gridpoint and level
with the prescribed IOPs to obtain
AOD, SSA and ASY of the aerosol mixture

Renew the 3 radiation schemes to use these fields for calculation of the aerosol transmission at each gridpoint and level

✓ done for hlradia only

Aerosol IOP=inherent optical properties MMR=mass mixing ratio

Advantages of this approach



1) Use of near-real time observation-based external aerosol data is optimal for regional NWP models

2) The same aerosol input applies for any radiation scheme

3) No need to know the optical properties for different aerosol species inside the radiation schemes

4) Aerosol MMRs might be used by the cloud-precipitation microphysics

5) The same approach is applicable for the use of real-time and climatological aerosol

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Diagnostic MUSC single-column experiments to study sensitivity of radiation to aerosol input

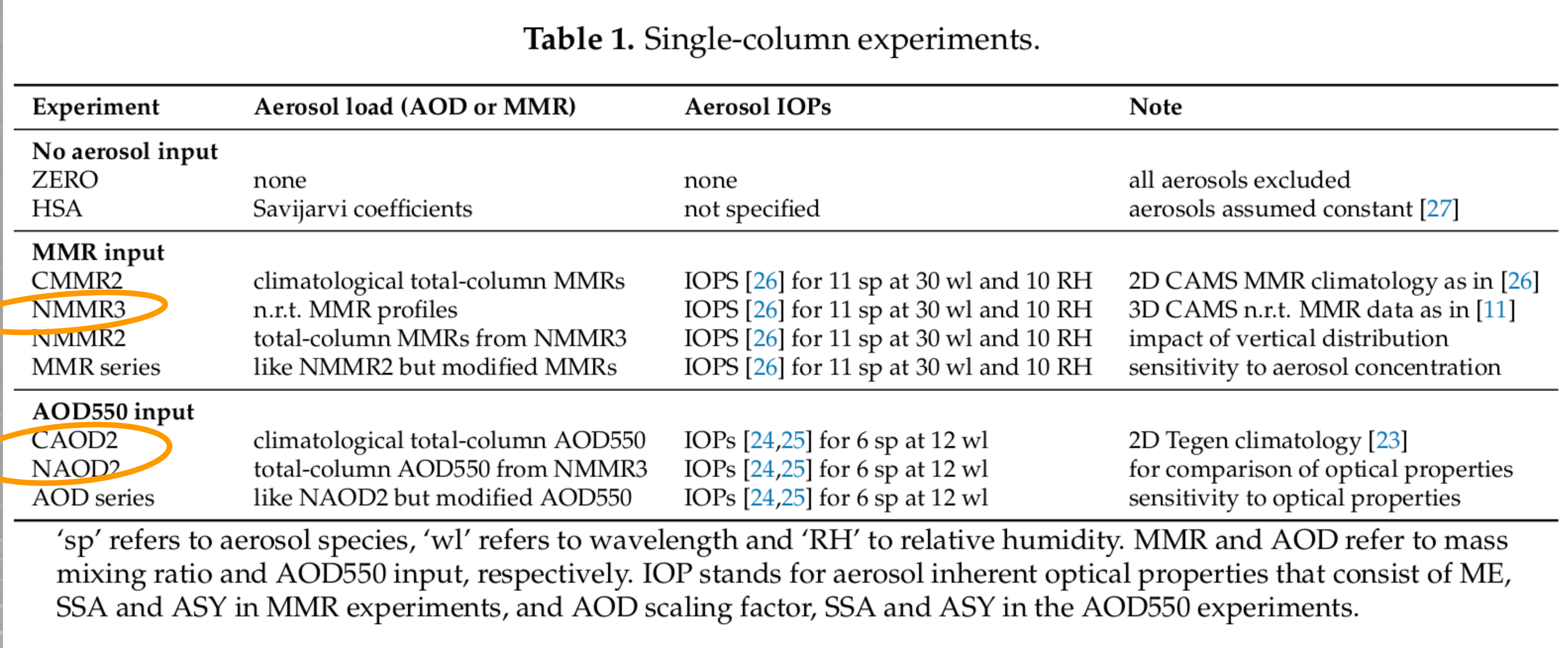


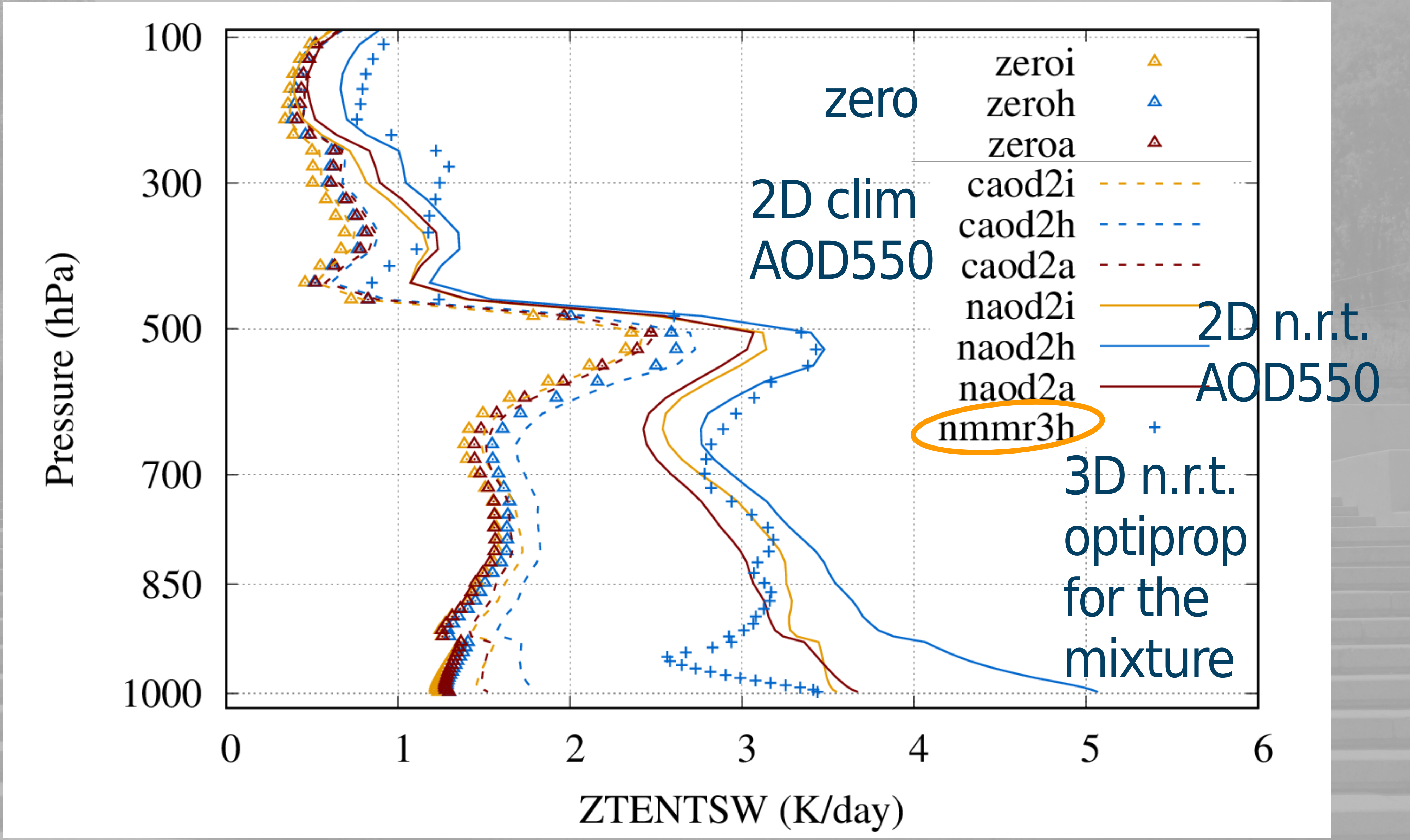
Table 1. Single-column experiments.

Experiment	Aerosol load (AOD or MMR)	Aerosol IOPs	Note
No aerosol input			
ZERO	none	none	all aerosols excluded
HSA	Savijarvi coefficients	not specified	aerosols assumed constant [27]
MMR input			
CMMR2	climatological total-column MMRs	IOPS [26] for 11 sp at 30 wl and 10 RH	2D CAMS MMR climatology as in [26]
NMMR3	n.r.t. MMR profiles	IOPS [26] for 11 sp at 30 wl and 10 RH	3D CAMS n.r.t. MMR data as in [11]
NMMR2	total-column MMRs from NMMR3	IOPS [26] for 11 sp at 30 wl and 10 RH	impact of vertical distribution
MMR series	like NMMR2 but modified MMRs	IOPS [26] for 11 sp at 30 wl and 10 RH	sensitivity to aerosol concentration
AOD550 input			
CAOD2	climatological total-column AOD550	IOPs [24,25] for 6 sp at 12 wl	2D Tegen climatology [23]
NAOD2	total-column AOD550 from NMMR3	IOPs [24,25] for 6 sp at 12 wl	for comparison of optical properties
AOD series	like NAOD2 but modified AOD550	IOPs [24,25] for 6 sp at 12 wl	sensitivity to optical properties

'sp' refers to aerosol species, 'wl' refers to wavelength and 'RH' to relative humidity. MMR and AOD refer to mass mixing ratio and AOD550 input, respectively. IOP stands for aerosol inherent optical properties that consist of ME, SSA and ASY in MMR experiments, and AOD scaling factor, SSA and ASY in the AOD550 experiments.

\+ no time-stepping - no clouds – passive surface
\+ real-time and climatological aerosol data extracted from 3D HARMONIE-AROME experiment output
\+ new MMRs & IOPs for aerosol mixture introduced only to HLRADIA

Example: temperature tendency due to SW radiation with zero aerosol and AOD550 input



zero

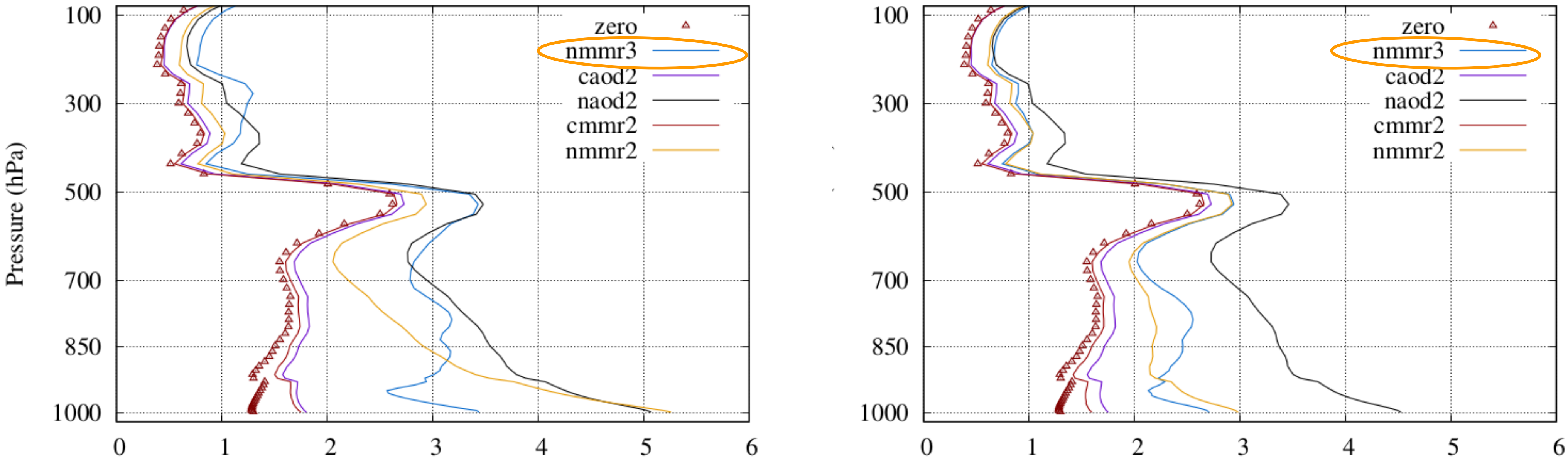
2D clim AOD550

2D n.r.t. AOD550

3D n.r.t. optiprop for the mixture

Figure details c.f. Atmosphere 2020, 11, 205; doi:10.3390/atmos11020205

Another example: temperature tendency due to SW radiation AOD550 v.s. new MMR & IOP



(a) (b)

Figure 6. Temperature tendencies due to SW radiation (K/day) at Badajoz: (**a**) all species included (**b**) black carbon excluded. *y*-axis shows pressure in hPa. Figure legends correspond to the experiments as given in Table 1.

Figure details c.f. Atmosphere 2020, 11, 205; doi:10.3390/atmos11020205

Cloud v.s. aerosol impact to radiation fluxes – a trial with prognostic MUSC

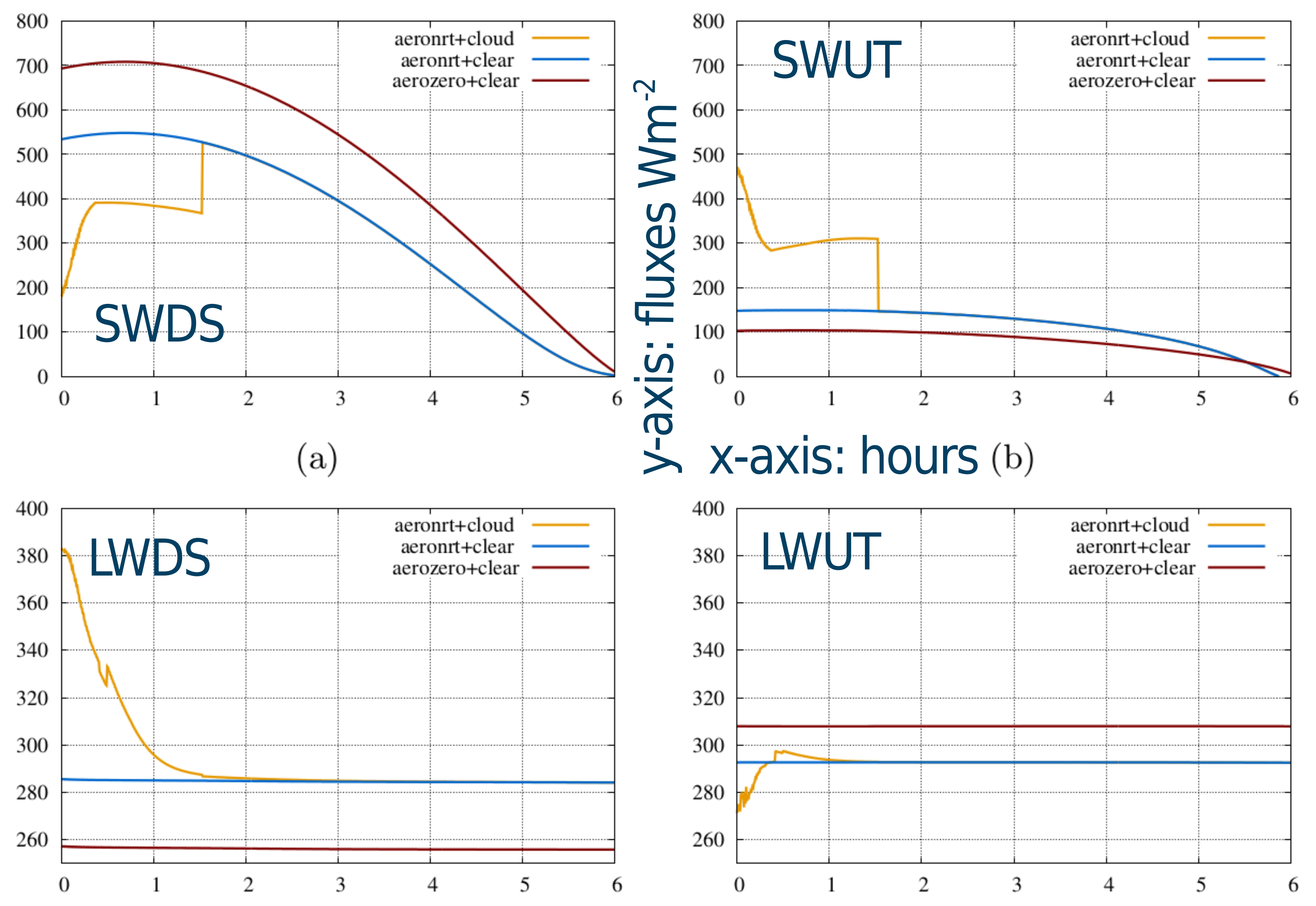


Figure details c.f. Gleeson et al.: HARMONIE-AROME Single-column Tools and Experiments. Submitted to Adv.Sci.Res, 2020

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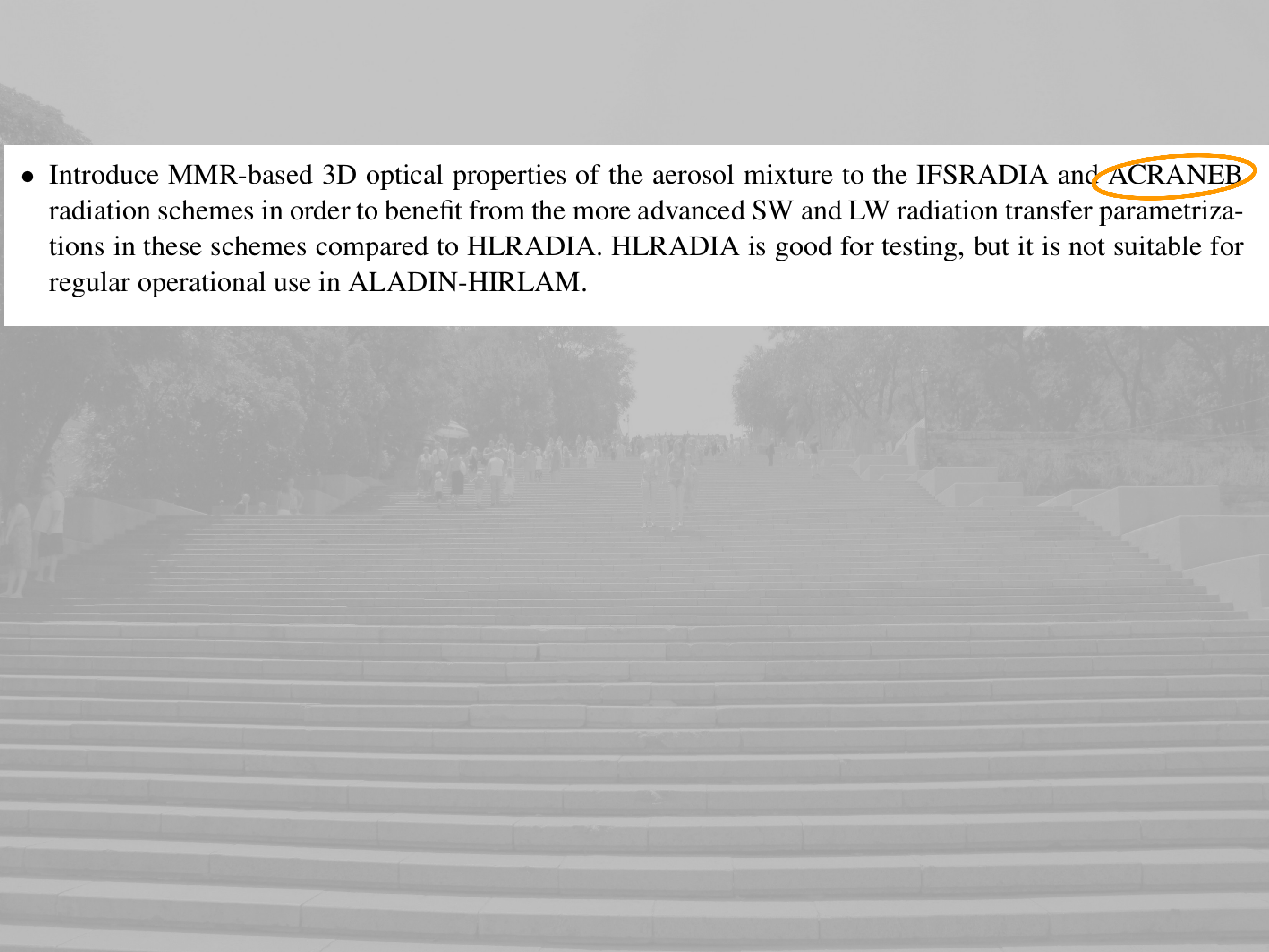

- Introduce MMR-based 3D optical properties of the aerosol mixture to the IFSRADIA and ACRANEB radiation schemes in order to benefit from the more advanced SW and LW radiation transfer parametrizations in these schemes compared to HLRADIA. HLRADIA is good for testing, but it is not suitable for regular operational use in ALADIN-HIRLAM.

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- Carry out extensive model-observation inter-comparisons for biomass burning, mineral dust intrusion, anthrophogenic and volcanic emission case studies in order to evaluate their impacts on local weather and radiation flux forecasts. MUSC is good for testing, but this kind of case studies should be done using the full 3D system, HARMONIE-AROME or another canonical configuration, preferably using ACRANEB or IFSRADIA for radiation parametrizations.

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- Consider introducing CAMS reanalysis-based aerosol climatology into HCLIM or other regional climate application within ALADIN-HIRLAM.

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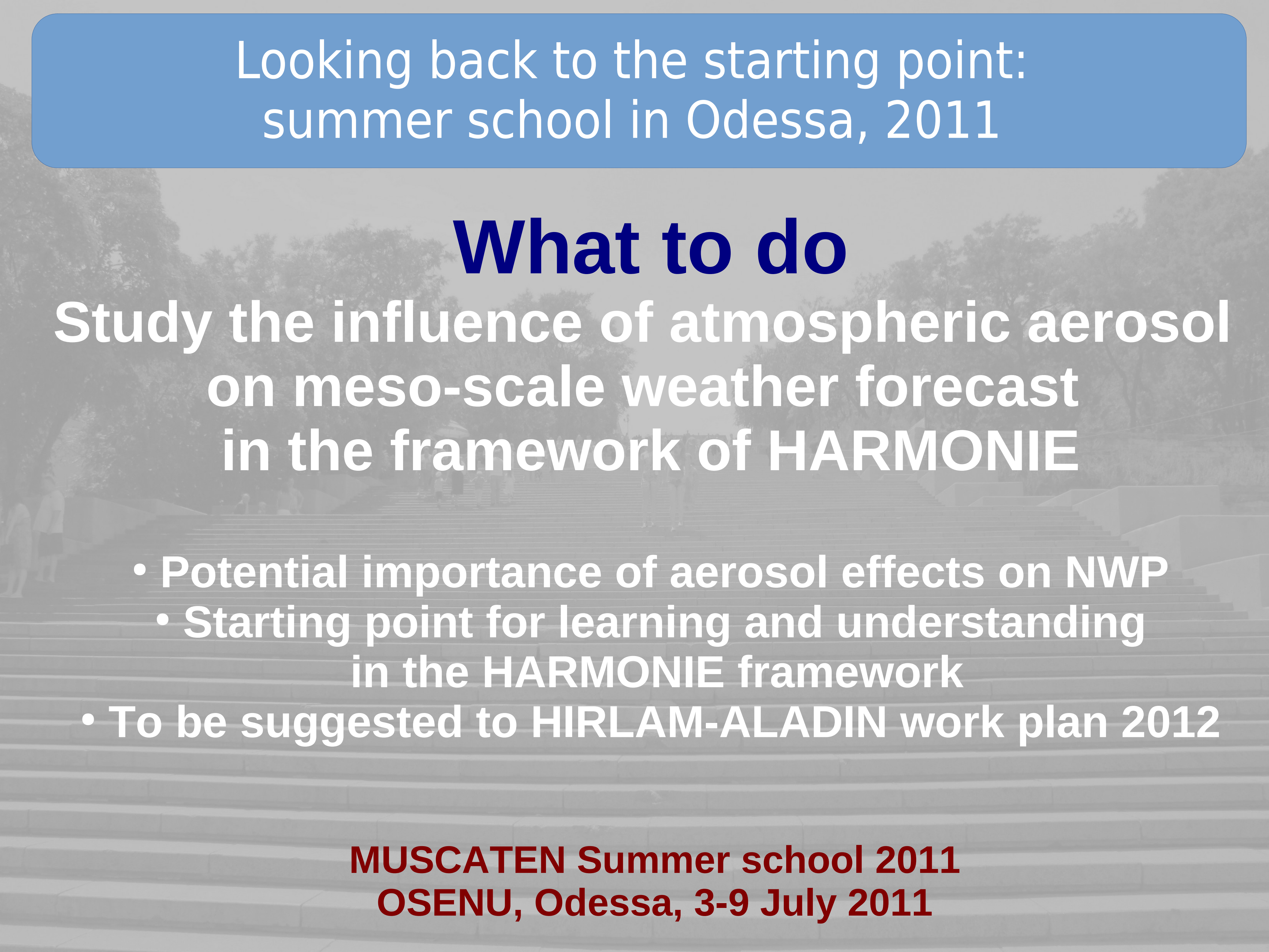
Looking back to the starting point: summer school in Odessa, 2011



What to do

Study the influence of atmospheric aerosol on meso-scale weather forecast in the framework of HARMONIE

- **Potential importance of aerosol effects on NWP**
- **Starting point for learning and understanding in the HARMONIE framework**
- **To be suggested to HIRLAM-ALADIN work plan 2012**

MUSCATEN Summer school 2011
OSENU, Odessa, 3-9 July 2011

Starting points

Enviro-HIRLAM experience on aerosol

AROME cloud microphysics and ECMWF radiation

SILAM forest fire data assimilation and modelling, operational experience with volcanic ash

FMI – University of Helsinki aerosol experience

Presently working with radiation + aerosol for HARMONIE NWP: Kristian Pagh Nielsen (DMI), Katya Horeva (RSHU), Emily Gleeson (Met Eireann), Tanya Ermakova (RSHU) ...

Some early references to HARMONIE-related aerosol publications:

https://sci-hub.tw/10.1016/j.atmosres.2014.10.011
https://sci-hub.tw/10.1016/j.atmosres.2014.11.018
https://sci-hub.tw/10.1016/j.atmosres.2015.08.001
https://sci-hub.tw/10.1016/j.atmosres.2016.01.003

First steps

Implementation of improved aerosol direct effect handling into HIRLAM radiation (hlradia)
- code by Kristian Nielsen & Bent Sass, DMI

Preliminary sensitivity studies using 1D HIRLAM and aerosol test data. Implementation of improved hlradia to HARMONIE AROME framework

Testing within ENVIRO-HIRLAM, using available integrated aerosol

Testing within HARMONIE AROME using climatological aerosol and comparing with ECMWF radiation scheme results

Next steps

Introduction of external aerosol to HARMONIE for a case study over summer 2010 Russian forest fires, comparison with Enviro-HIRLAM results

Feasibility study of aerosol and cloud microphysics interactions in HARMONIE – what could be improved in formulations and consistency between cloud and radiation handling

Starting from fog and stratus – as part of the stable boundary layer initiative?

Merci pour votre attention / Hvala za vašo pozornost!

Odessa, Potemkin stairs 2011

Merci pour votre attention / Hvala za vašo pozornost!

Wildfires on the main road from east to Havana, Cuba, 15.3.2020. Photo LR

Parametrization of the radiative transfer

Solar (SW) radiation: scattering and absorption
Terrestrial (LW) radiation: emission, absoption, scattering

In the air:
Gas molecules
Cloud droplets and crystals
Aerosol particles

Physico-chemical properties:
Mass concentration
Size
Shape
Composition

Optical properties:
Optical depth
Single scattering albedo
Asymmetry factor

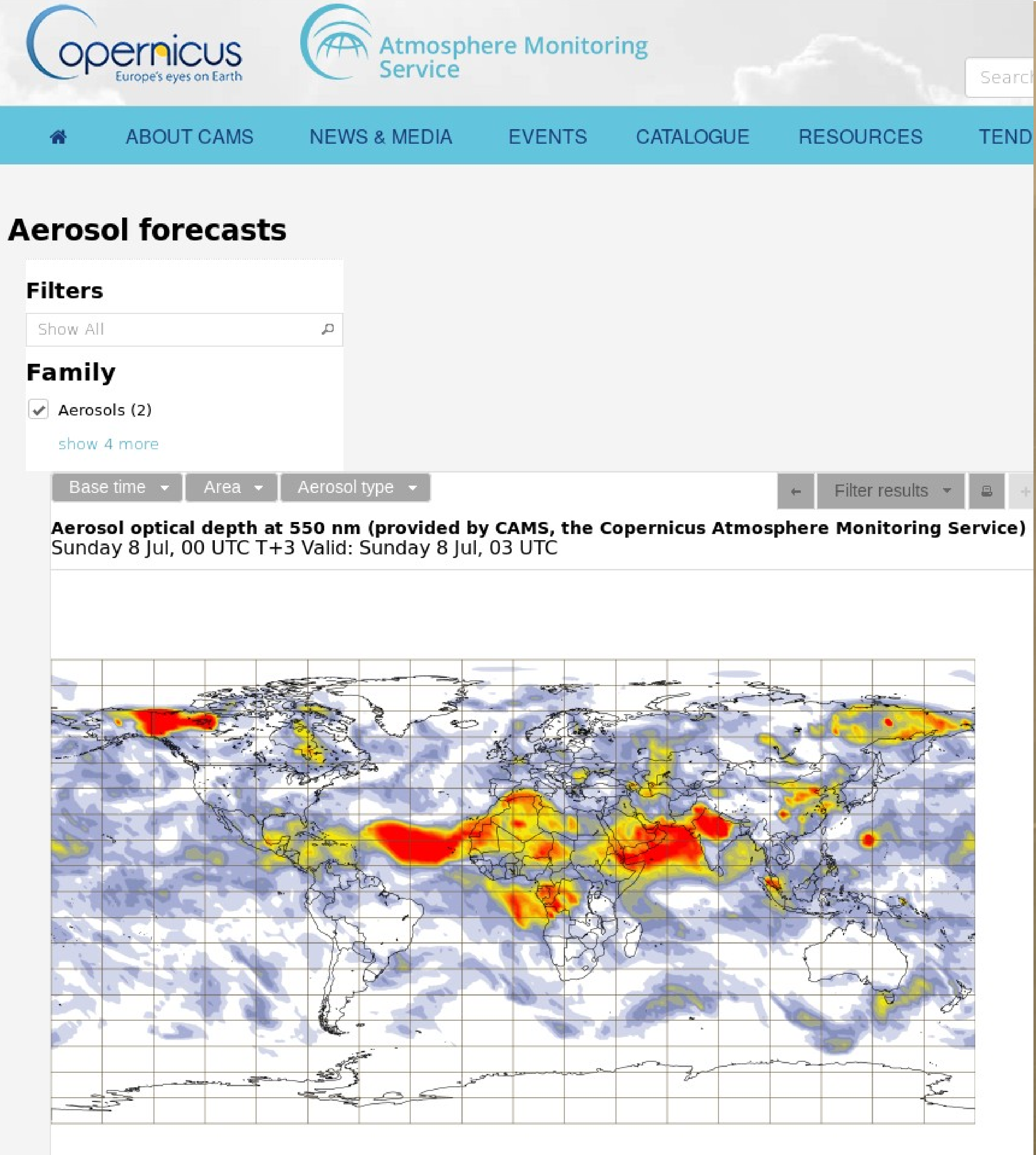
Grid-scale variables:
T, q_v, q_i, q_l, q_s, q_g
Aerosol (concentration)
Radiative fluxes

Surface-atmosphere radiative interactions

Surface albedo and emissivity
Orographic radiation effects

Characteristics of surface types
Surface elevation

Aerosol data are available from CAMS



Aerosol forecasts

Filters

Show All

Family

☑ Aerosols (2)

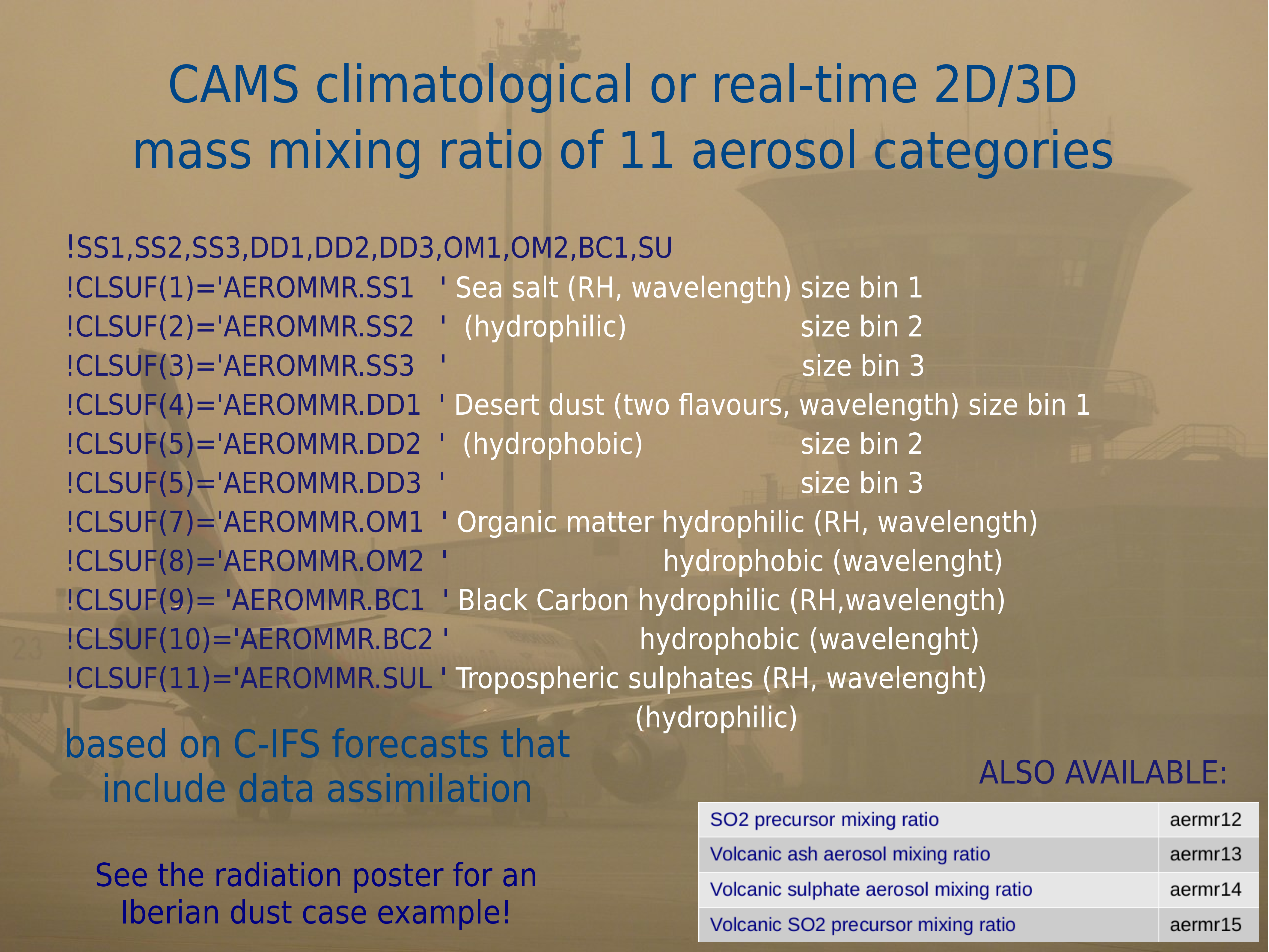
show 4 more

Aerosol optical depth at 550 nm (provided by CAMS, the Copernicus Atmosphere Monitoring Service)
Sunday 8 Jul, 00 UTC T+3 Valid: Sunday 8 Jul, 03 UTC

Climatology and near-real-time

Mass concentration (x,y,z)

Inherent optical properties:
mass extinction, single scattering albedo, asymmetry factor as functions of wavelength and aerosol species



CAMS climatological or real-time 2D/3D mass mixing ratio of 11 aerosol categories

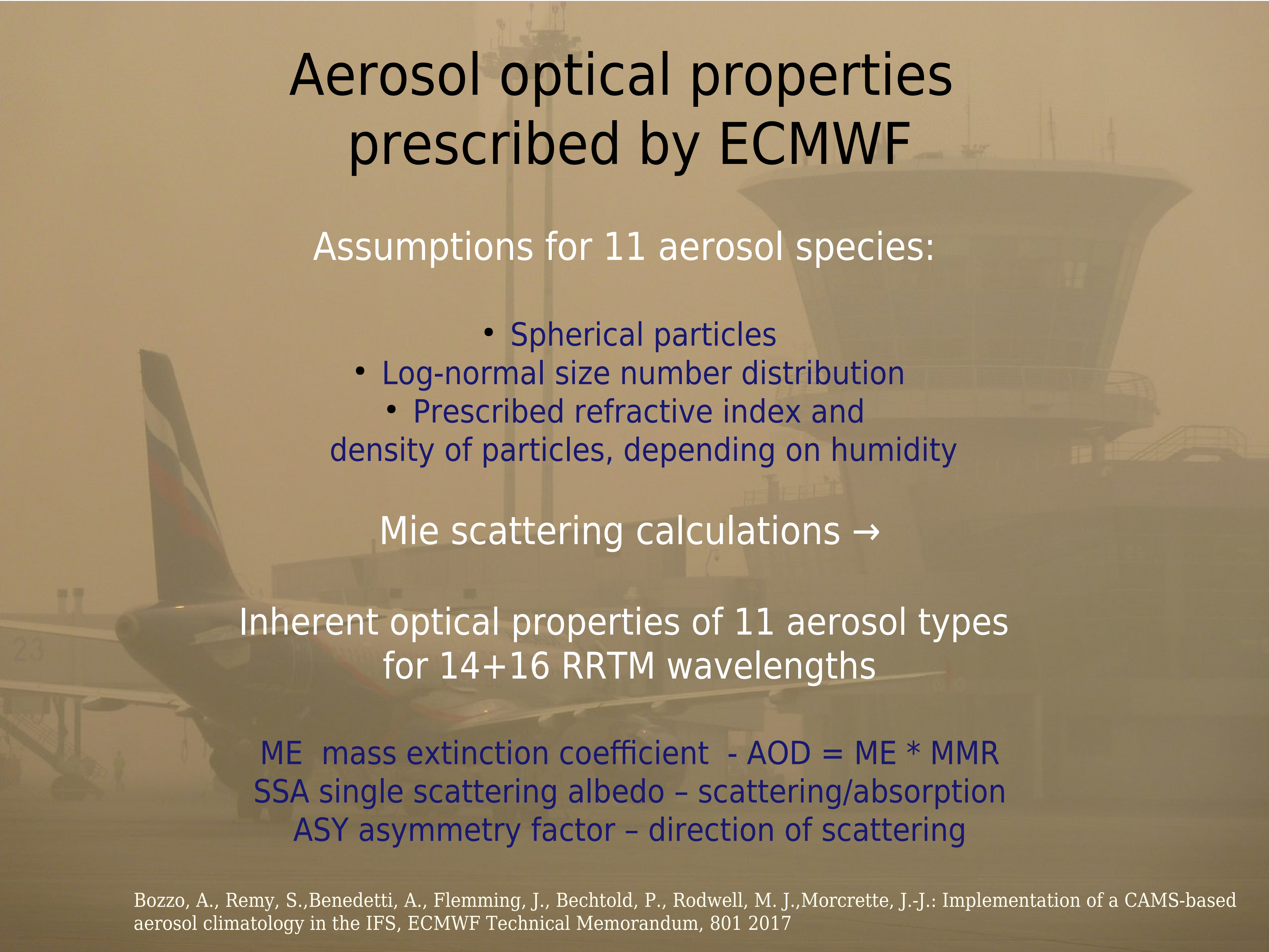
```
!SS1,SS2,SS3,DD1,DD2,DD3,OM1,OM2,BC1,SU
!CLSUF(1)='AEROMMR.SS1   ' Sea salt (RH, wavelength) size bin 1
!CLSUF(2)='AEROMMR.SS2   '  (hydrophilic)             size bin 2
!CLSUF(3)='AEROMMR.SS3   '                            size bin 3
!CLSUF(4)='AEROMMR.DD1  ' Desert dust (two flavours, wavelength) size bin 1
!CLSUF(5)='AEROMMR.DD2  '  (hydrophobic)              size bin 2
!CLSUF(5)='AEROMMR.DD3  '                             size bin 3
!CLSUF(7)='AEROMMR.OM1  ' Organic matter hydrophilic (RH, wavelength)
!CLSUF(8)='AEROMMR.OM2  '                 hydrophobic (wavelenght)
!CLSUF(9)= 'AEROMMR.BC1  ' Black Carbon hydrophilic (RH,wavelength)
!CLSUF(10)='AEROMMR.BC2 '                hydrophobic (wavelenght)
!CLSUF(11)='AEROMMR.SUL ' Tropospheric sulphates (RH, wavelenght)
                                         (hydrophilic)
```

based on C-IFS forecasts that include data assimilation

See the radiation poster for an Iberian dust case example!

ALSO AVAILABLE:

SO2 precursor mixing ratio	aermr12
Volcanic ash aerosol mixing ratio	aermr13
Volcanic sulphate aerosol mixing ratio	aermr14
Volcanic SO2 precursor mixing ratio	aermr15



Aerosol optical properties prescribed by ECMWF

Assumptions for 11 aerosol species:

- Spherical particles
- Log-normal size number distribution
- Prescribed refractive index and density of particles, depending on humidity

Mie scattering calculations →

Inherent optical properties of 11 aerosol types for 14+16 RRTM wavelengths

ME mass extinction coefficient - AOD = ME * MMR
SSA single scattering albedo – scattering/absorption
ASY asymmetry factor – direction of scattering

Bozzo, A., Remy, S.,Benedetti, A., Flemming, J., Bechtold, P., Rodwell, M. J.,Morcrette, J.-J.: Implementation of a CAMS-based aerosol climatology in the IFS, ECMWF Technical Memorandum, 801 2017

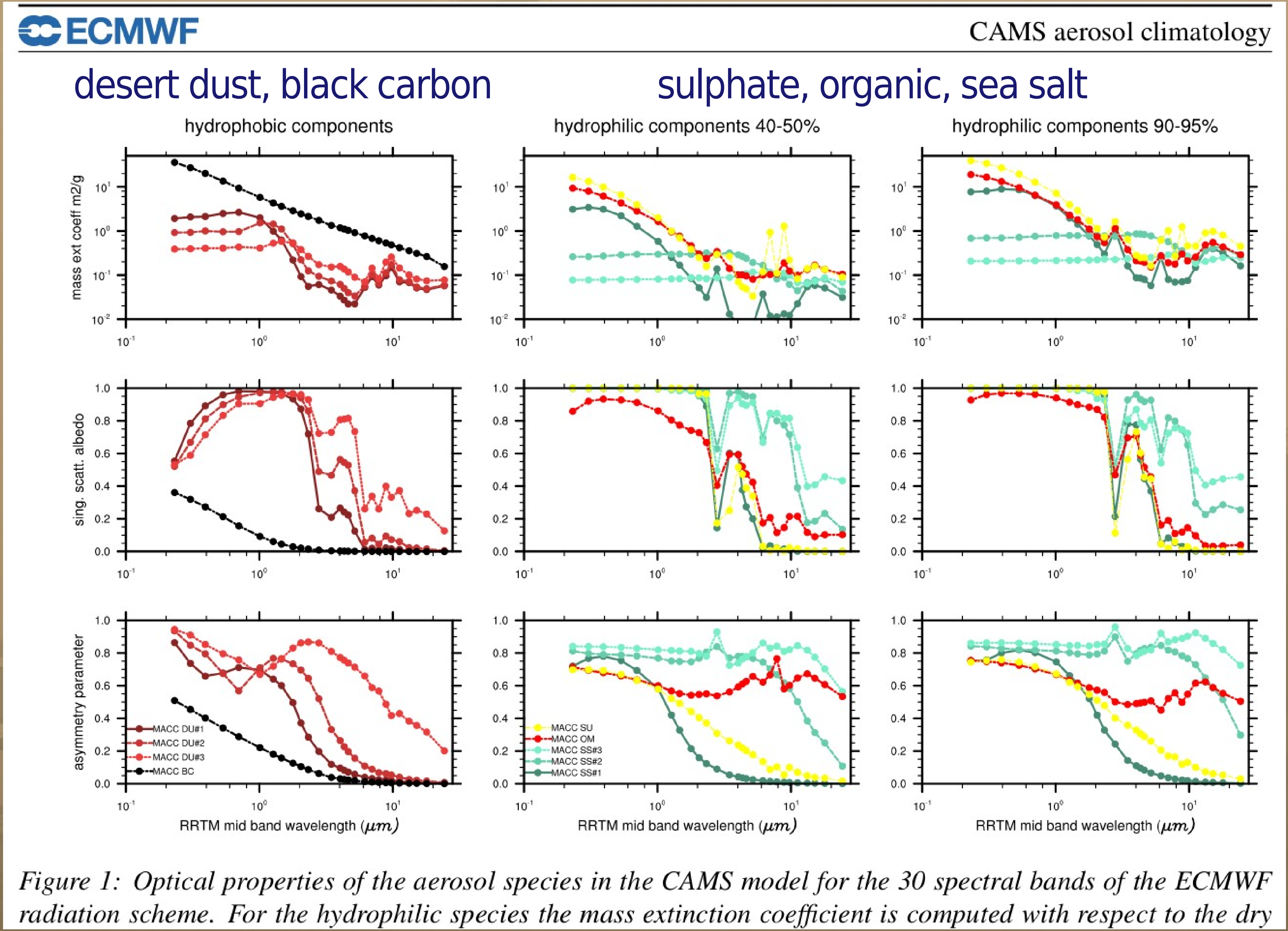
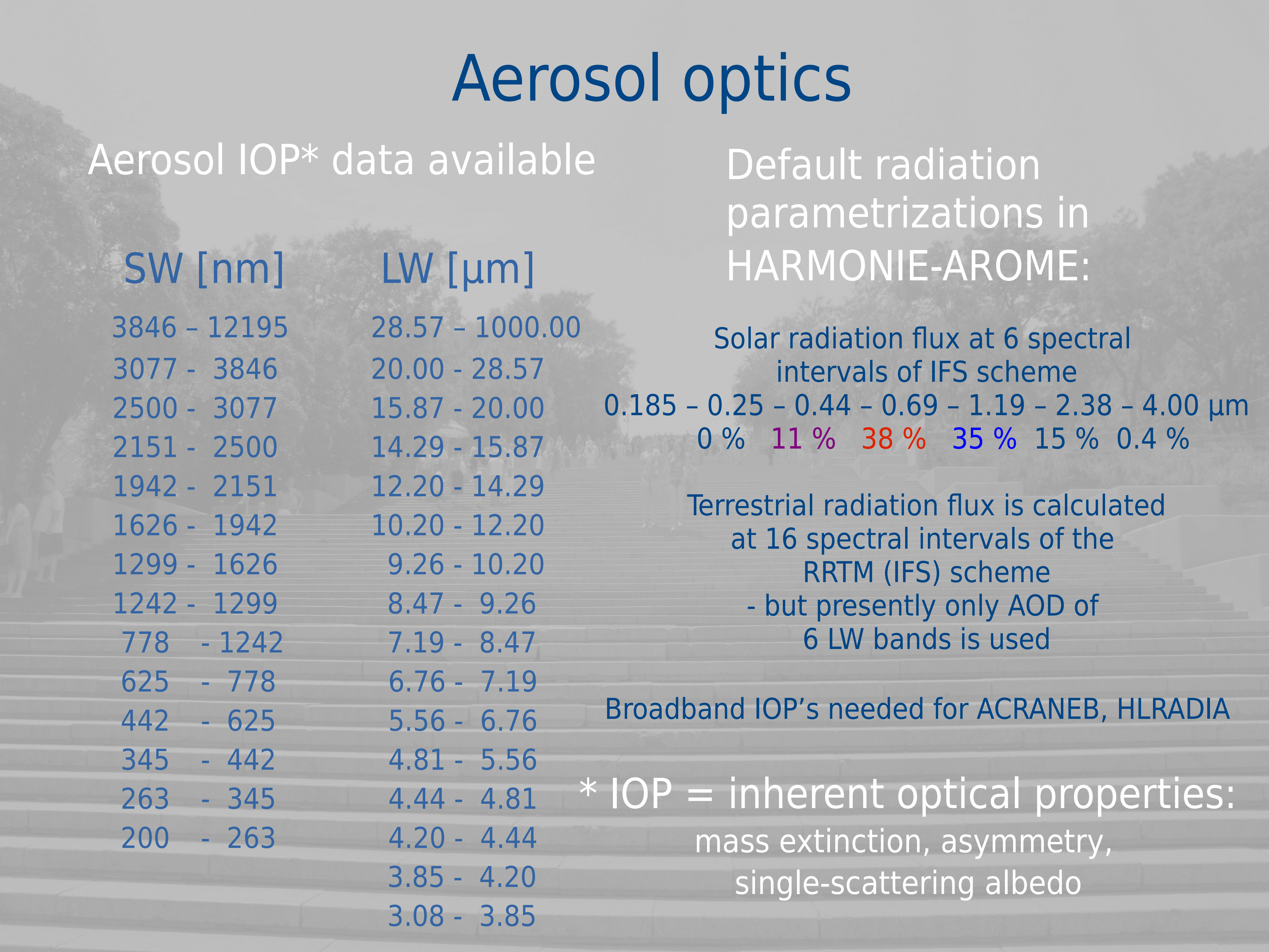


Figure 1: Optical properties of the aerosol species in the CAMS model for the 30 spectral bands of the ECMWF radiation scheme. For the hydrophilic species the mass extinction coefficient is computed with respect to the dry

Bozzo, A., Remy, S.,Benedetti, A., Flemming, J., Bechtold, P., Rodwell, M. J.,Morcrette, J.-J.: Implementation of a CAMS-based aerosol climatology in the IFS, ECMWF Technical Memorandum, 801 2017



Aerosol optics

Aerosol IOP* data available

SW [nm]	LW [µm]
3846 – 12195	28.57 – 1000.00
3077 - 3846	20.00 - 28.57
2500 - 3077	15.87 - 20.00
2151 - 2500	14.29 - 15.87
1942 - 2151	12.20 - 14.29
1626 - 1942	10.20 - 12.20
1299 - 1626	9.26 - 10.20
1242 - 1299	8.47 - 9.26
778 - 1242	7.19 - 8.47
625 - 778	6.76 - 7.19
442 - 625	5.56 - 6.76
345 - 442	4.81 - 5.56
263 - 345	4.44 - 4.81
200 - 263	4.20 - 4.44
	3.85 - 4.20
	3.08 - 3.85

Default radiation parametrizations in HARMONIE-AROME:

Solar radiation flux at 6 spectral
intervals of IFS scheme
0.185 – 0.25 – 0.44 – 0.69 – 1.19 – 2.38 – 4.00 µm
0 % 11 % 38 % 35 % 15 % 0.4 %

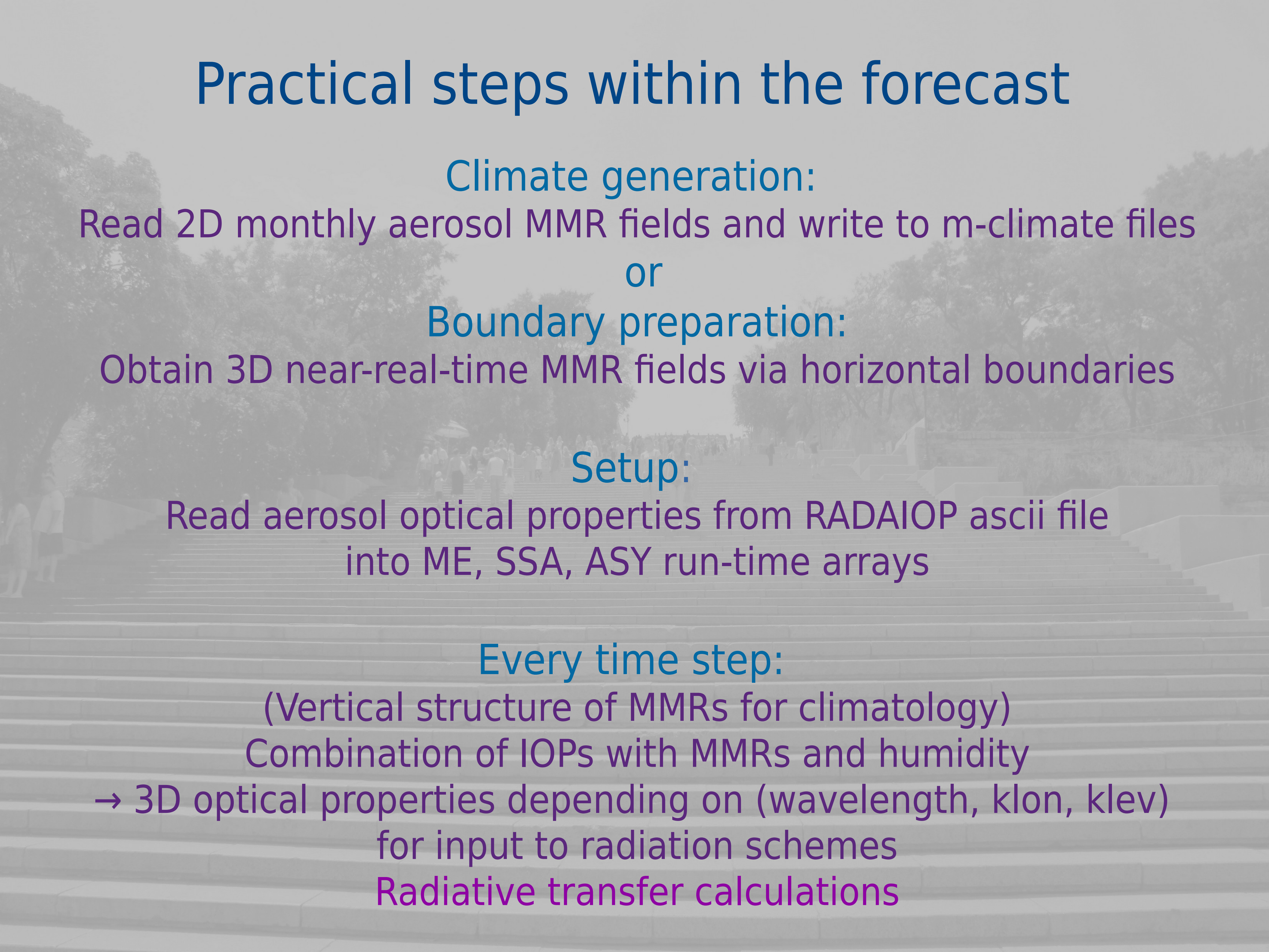
Terrestrial radiation flux is calculated
at 16 spectral intervals of the
RRTM (IFS) scheme
- but presently only AOD of
6 LW bands is used

Broadband IOP's needed for ACRANEB, HLRADIA

* IOP = inherent optical properties:

mass extinction, asymmetry,
single-scattering albedo

Practical steps within the forecast



Climate generation:

Read 2D monthly aerosol MMR fields and write to m-climate files

or

Boundary preparation:

Obtain 3D near-real-time MMR fields via horizontal boundaries

Setup:

Read aerosol optical properties from RADAIOP ascii file
into ME, SSA, ASY run-time arrays

Every time step:

(Vertical structure of MMRs for climatology)
Combination of IOPs with MMRs and humidity
→ 3D optical properties depending on (wavelength, klon, klev)
for input to radiation schemes
Radiative transfer calculations

```
src/arpifs/
├── c9xx
│   └── incli0.F90
├── climate
│   └── updcli.F90
├── control
│   └── cprep1.F90
├── fullpos
│   ├── fpiniphy.F90
│   ├── hpos.F90
│   ├── sufprfpds.F90
│   └── sufptr2.F90
├── module
│   ├── surface_fields_mix.F90
```

```
src/aladin
└── c9xx
    ├── ebicli.F90
    └── eincli9.F90
```

```
├── module
│   ├── surface_fields_mix.F90
│   ├── yoaiop.F90
│   ├── yoerad.F90
│   ├── yomafn.F90
│   ├── yomlun.F90
│   └── yomphy.F90
├── namelist
│   ├── namafn.nam.h
│   |------namcli.nam.h
│   └── namphy.nam.h
│   ├── suaersn.F90
│   └── suecrad.F90
└── setup
    ├── su0phy.F90
    ├── suafn1.F90
    ├── suafn2.F90
    ├── suafn3.F90
    ├── suaiop.F90
    └── su_surf_flds.F90
```

```
├── phys_dmn
│   ├── apl_arome.F90
│   ├── aplpar.F90
│   └── mf_phys.F90
├── phys_radi
│   ├── aeropt.F90
│   ├── aero_rt6.F90
│   ├── radaer.F90
│   ├── suaersn.F90
│   └── suecrad.F90
```

Later:

ecrad
acraneb2
hlradia
- modifications of
  several subroutines
  to use new aerosol IOPs

Data from Alessio → HIRLAM-ALADIN climate/prescribed

MMRclim_gbst_2003-2011.nc → mmr.cams.m01_GL
macc_opt_43R1.nc → const/rrtm_const/RADAIOP

Data directly from CAMS

3D real-time aerosol for
radiation and
cloud microphysics